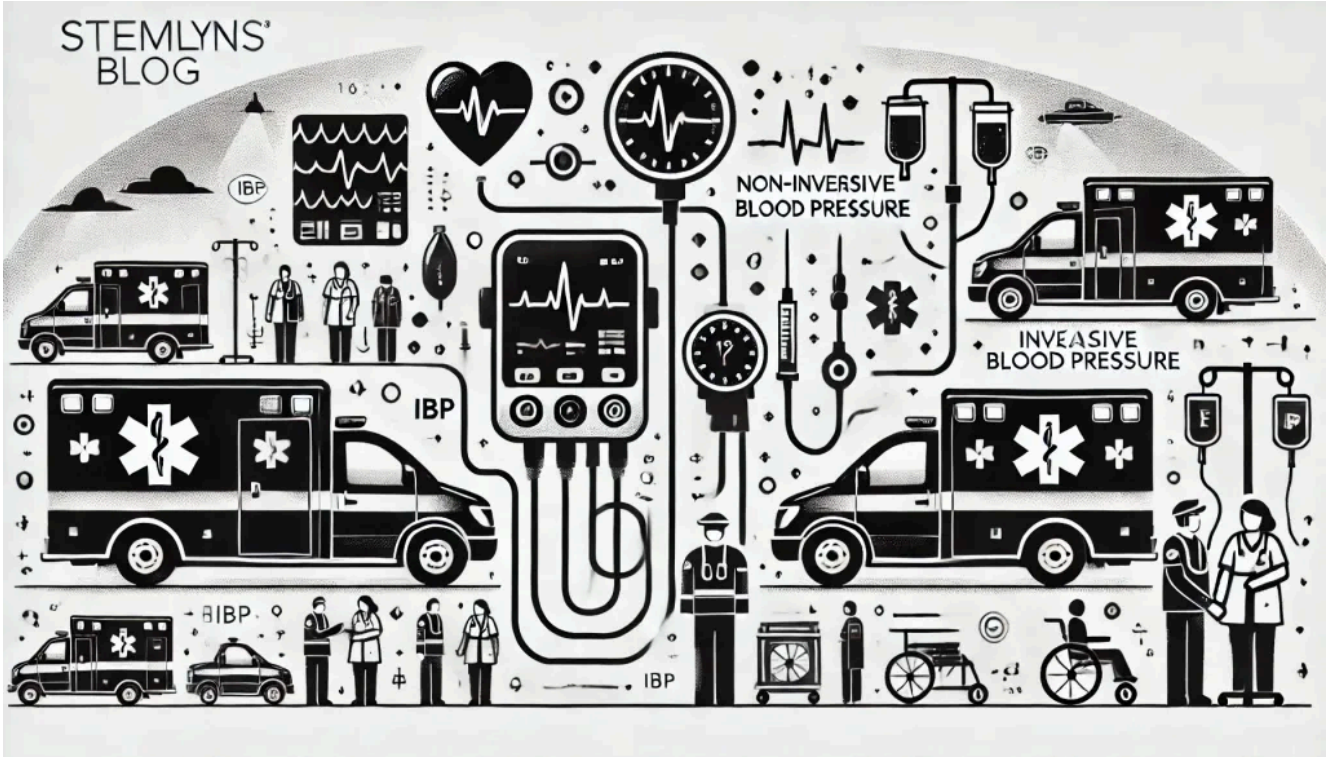


Non-invasive or arterial pressure monitoring in PHEM?

By Simon Carley / September 29, 2024 / #FOAMed, Emergency Medicine, Prehospital Care

Background

Here in Virchester we have started putting in a lot more invasive arterial lines for critically ill and injured patients. What's clear is that there are significant differences between what I see on the invasive monitoring and on the non-invasive monitoring. I've also noticed wild differences between two different oscillometric non-invasive devices on the same patient. All of this has made me increasingly sceptical of blood pressures, but what really is the magnitude and significant of the difference?

Clearly, accurate blood pressure (BP) monitoring is essential in the emergency management of critically ill patients. Traditionally, non-invasive blood pressure (NIBP) measurements using oscillometric cuff devices are the most common approach and this would be considered standard care in Virchester. It's simple to use and less invasive compared with intra-arterial blood pressure (IBP) monitoring, and can be delivered with easily available kit and minimal training. In contrast, in my hospital practice invasive monitoring remains the gold standard for accuracy in critically ill patients. Despite the fact that oscillometric NIBP devices are known to be less reliable at physiological extremes and may be affected by factors like vibration during patient transport they are still widely used.

In hospital settings, direct intra-arterial BP monitoring is routinely used for high-risk patients. This method provides continuous BP readings, helping to guide resuscitation efforts more precisely.

PHEM services are developing, and increasingly services in the UK are considering (or have already) shifting to IABP as standard of care for selected patients, but what does this really mean in practice and are the differences that great? Fortunately a recent study published in SJTRM helps answer this question. This study aimed to compare NIBP and IBP measurements in pre-hospital environments and determine the reliability of NIBP readings for critically ill patients. The abstract is below, but as always we recommend you read the full paper yourself.

The Abstract

Background *Blood pressure monitoring is important in the pre-hospital management of critically ill patients. Non-invasive blood pressure (NIBP) measurements are commonly used but the accuracy of standard oscillometric cuff devices may be affected by extremes of physiology and adverse conditions (e.g. vibration) during transport. This study aimed to quantify the accuracy of NIBP measurements amongst patients requiring pre-hospital critical care.*

Methods *A retrospective cohort study was undertaken using data from patients treated by a pre-hospital critical team between 1st May 2020 and 30th April 2023 that had NIBP measured concurrently with invasive blood pressure (IBP) arterial manometry. An acceptable difference was determined a priori to be <20mmHg for systolic blood pressure (SBP) and diastolic blood pressure (DBP), and <10mmHg for mean arterial pressure (MAP). The primary outcome was "pairwise agreement", i.e. the proportion of paired observations that fell within this range of acceptability. Bland-Altman plots were constructed together with 95% limits of agreement to visualise differences between pairs of data. Associations with patient age, reason for critical care, transport status, haemodynamic shock, severe hypertension, and arterial catheter position were explored in univariate analyses and by fitting multivariable logistic regression models.*

Results *There were 2,359 paired measurements from 221 individual patients with a median age of 57. The most frequent reason for transport was cardiac arrest (79, 35.7%). Bland-Altman analyses suggested unacceptably wide limits of agreement with NIBP overestimating both SBP and MAP during hypotension and underestimating these values during hypertension. Haemodynamic shock (SBP<90mmHg) was independently associated with reduced pairwise agreement for SBP (adjusted odds ratio [aOR] 0.52, 95% CI 0.35 to 0.77), DBP (aOR 0.65, 95% CI 0.42 to 0.99) and MAP (aOR 0.53, 95% CI 0.36 to 0.78) and severe hypertension (SBP>160mmHg) with reduced pairwise agreement for SBP (aOR 0.17, 95% CI 0.11 to 0.27). There was no association between patient transport and agreement between the methods for SBP, DBP, or MAP.*

Conclusions *Non-invasive blood pressure measurements are often inaccurate in the pre-hospital critical care setting, particularly in patients with haemodynamic instability. Clinicians should be cautious when interpreting NIBP measurements and consider direct arterial pressure monitoring when circumstances allow.*

What kind of study is this?

This study is a retrospective cohort analysis, utilising data from Thames Valley Air Ambulance (TVAA), a pre-hospital critical care service in England. It examined paired measurements of NIBP and IBP taken from adult patients attended by the air ambulance team between May 2020 and April 2023. Although this is an observational study, which often is considered a low form of evidence, in this setting it's arguably exactly what we want. We already known that the two methods will differ, but by conducting this study in real-world pre-hospital conditions, accounting for the effects of transport, patient acuity, and physiological extremes it gives us a realistic view of what really happens in practice (and with the sort of patients we treat).

The study used Bland-Altman plots to visually represent the agreement between NIBP and IBP and employed statistical models to identify factors influencing measurement discrepancies. I love a Bland-Altman plot and would recommend you learn to love them too, especially if you are interested in looking at continuous diagnostic data. They are especially useful when looking at agreement (and SO much better than

doing simple correlations). This approach provides a robust understanding of the accuracy and potential limitations of NIBP in critically ill patients before they reach the hospital.

Tell me about the patients

The study included 221 patients with a median age of 57 years (interquartile range: 43–72 years). The most common reasons for pre-hospital critical care were major trauma (83 patients, 37.5%) and cardiac arrest (79 patients, 35.7%). The inclusion criteria required that patients had at least one concurrent NIBP and IBP measurement recorded, with 2,359 paired observations available for analysis.

Arterial catheters for IBP measurement were most frequently placed in the radial artery (155, 70.1%), while others were positioned in the femoral artery (34, 15.4%). Transport status was also considered, with 70.7% of blood pressure measurements taken during transport to hospital.

What were the measured outcomes in this study?

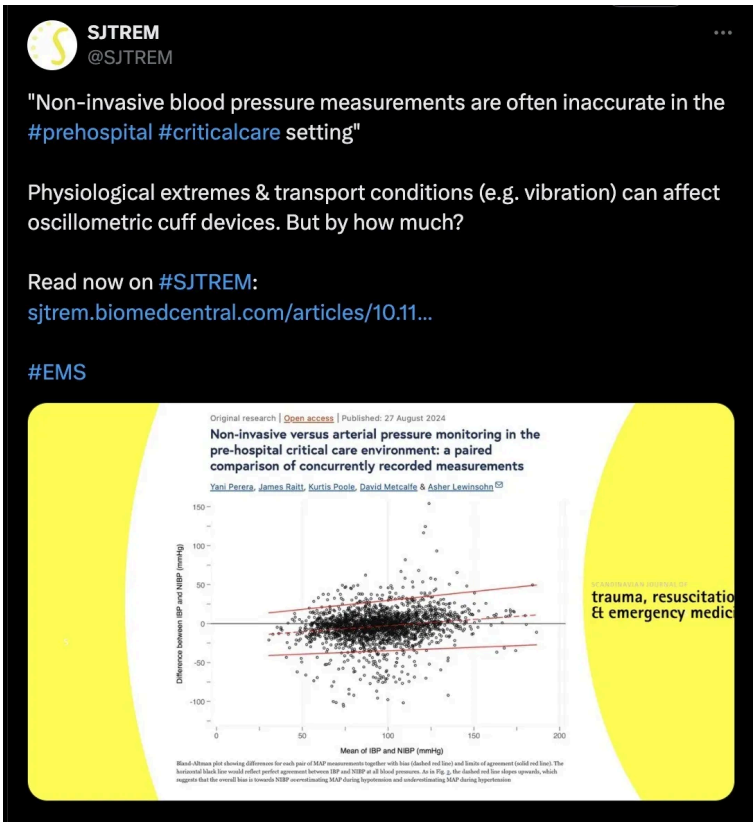
The primary outcome was “pairwise agreement” between NIBP and IBP measurements. An acceptable difference was predefined as <20 mmHg for systolic BP (SBP) and diastolic BP (DBP) and <10 mmHg for mean arterial pressure (MAP). These thresholds were considered clinically significant as deviations beyond these limits may impact patient management, such as initiating or adjusting vasopressor therapy. You might consider that these ‘acceptable’ differences are quite wide, and I would agree, but it’s a judgement call and they are reasonable.

Secondary outcomes included associations between NIBP-IBP agreement and various factors such as patient age, clinical reason for critical care, transport status, haemodynamic shock (defined as IBP SBP <90 mmHg), severe hypertension (SBP >160 mmHg), and arterial catheter position.

What are the main results?

The results showed significant discrepancies between NIBP and IBP readings, particularly at the extremes of blood pressure:

- **Overall Agreement: Only 63.8% of SBP, 75.8% of DBP, and 54.8% of MAP measurements fell within the pre-defined acceptable ranges.** If this does not concern you then you’ve not understood the results.
- **Bland-Altman Analysis**: NIBP readings tended to overestimate SBP and MAP at low BP values (hypotension) and underestimate these values at high BP values (hypertension). DBP was consistently overestimated across its range.
- **Impact of Haemodynamic Instability**: Haemodynamic shock was associated with lower agreement for SBP (adjusted odds ratio [aOR] 0.52, 95% CI 0.35–0.77), DBP (aOR 0.65, 95% CI 0.42–0.99), and MAP (aOR 0.53, 95% CI 0.36–0.78).
- **Impact of Severe Hypertension**: Severe hypertension was associated with markedly reduced agreement for SBP (aOR 0.17, 95% CI 0.11–0.27), while DBP and MAP were less affected.
- **Impact of Arterial Catheter Site**: Femoral arterial lines were associated with reduced agreement for MAP (aOR 0.65, 95% CI 0.46–0.91) compared to radial lines, indicating a potential influence of catheter position on IBP accuracy.



This tweet also shows a nice Bland-Altman plot. This show differences for each pair of SBP measurements together with bias (dashed red line) and limits of agreement (solid red line). The horizontal black line would reflect perfect agreement between IBP and NIBP at all blood pressures. In this case, the dashed red line slopes upwards, which suggests that the overall bias is towards NIBP *over*estimating SBP during hypotension and *under*estimating SBP during hypertension

Are these results believable?

First up, these findings are consistent with previous literature indicating that NIBP is less accurate at extremes of BP and in haemodynamically unstable patients. However, there are a few concerns and biases in the methods and selection of results for analysis:

- Measurement Exclusions: The study excluded implausible measurements, which might have introduced a selection bias, potentially overestimating the overall agreement between NIBP and IBP. If anything, this would make the results even worse, so it does not change the overall conclusion. It also reflects real-world practice, as that's what we often do when we see something implausible. We ignore it and try to get a new reading.
- Acceptable Agreement Thresholds: The pre-defined agreement thresholds were broader than in other studies, which may lead to an overestimation of the reliability of NIBP measurements.
- Single Centre Data: All data were collected from a single air ambulance service, which may limit the generalisability of the findings to other pre-hospital care systems. This is always an issue with single centre studies, although the findings here concur with my experience too (so am inclined to agree with them).
- Transport Mode: The study did not differentiate between road and air transport, which could have affected the results, given the different environmental conditions that influence NIBP accuracy.

Should we change practice based on this study?

Yes. Blood pressure is a fundamental measurement in managing critically ill and unwell patients. This paper tells us that we cannot really trust NIBP and that's a problem, so we should aspire to IABP where possible. In situations where precise BP control is critical—such as severe traumatic brain injury, spinal cord injury, or post-cardiac arrest care—direct arterial BP monitoring should be considered and done where possible. That said, it is not without difficulty, may take time (although in reality, very little usually) and can lead to complications.

All of this of course is predicated on the availability of kit, training, people, time, location etc. and there will be many many occasions where IABP cannot be delivered. At the moment in the UK it is limited to PHEM teams and so the reach to the public and the wider population is severely limited.

Time is often quoted as an issue but the London HEMS experience would suggest that it adds about 2mins to scene time on average and that (IMHO) is acceptable. In my practice I set a timer and if the line is not in and secure within 5mins then I usually abandon as it's potentially heading for task fixation and other time related factors may get worse (e.g. bleeding).

Summary

This retrospective cohort study highlights the limitations of NIBP in the pre-hospital critical care environment, showing significant inaccuracies at extremes of BP. NIBP reliability is questionable in haemodynamically unstable patients. These findings should prompt pre-hospital teams to be cautious when interpreting NIBP readings and consider incorporating IABP monitoring when conditions allow, to improve patient outcomes in critical scenarios.

References and further reading

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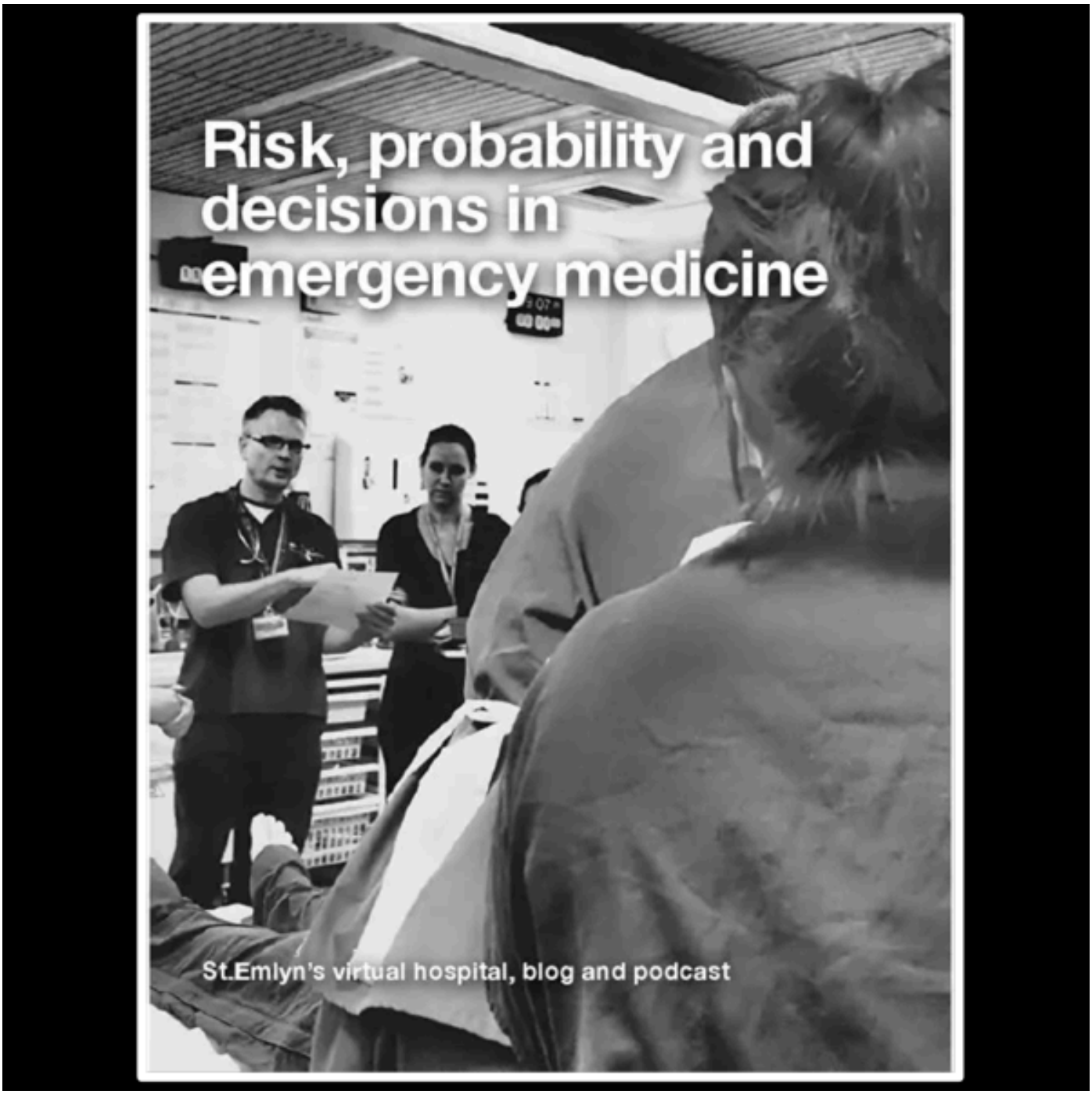
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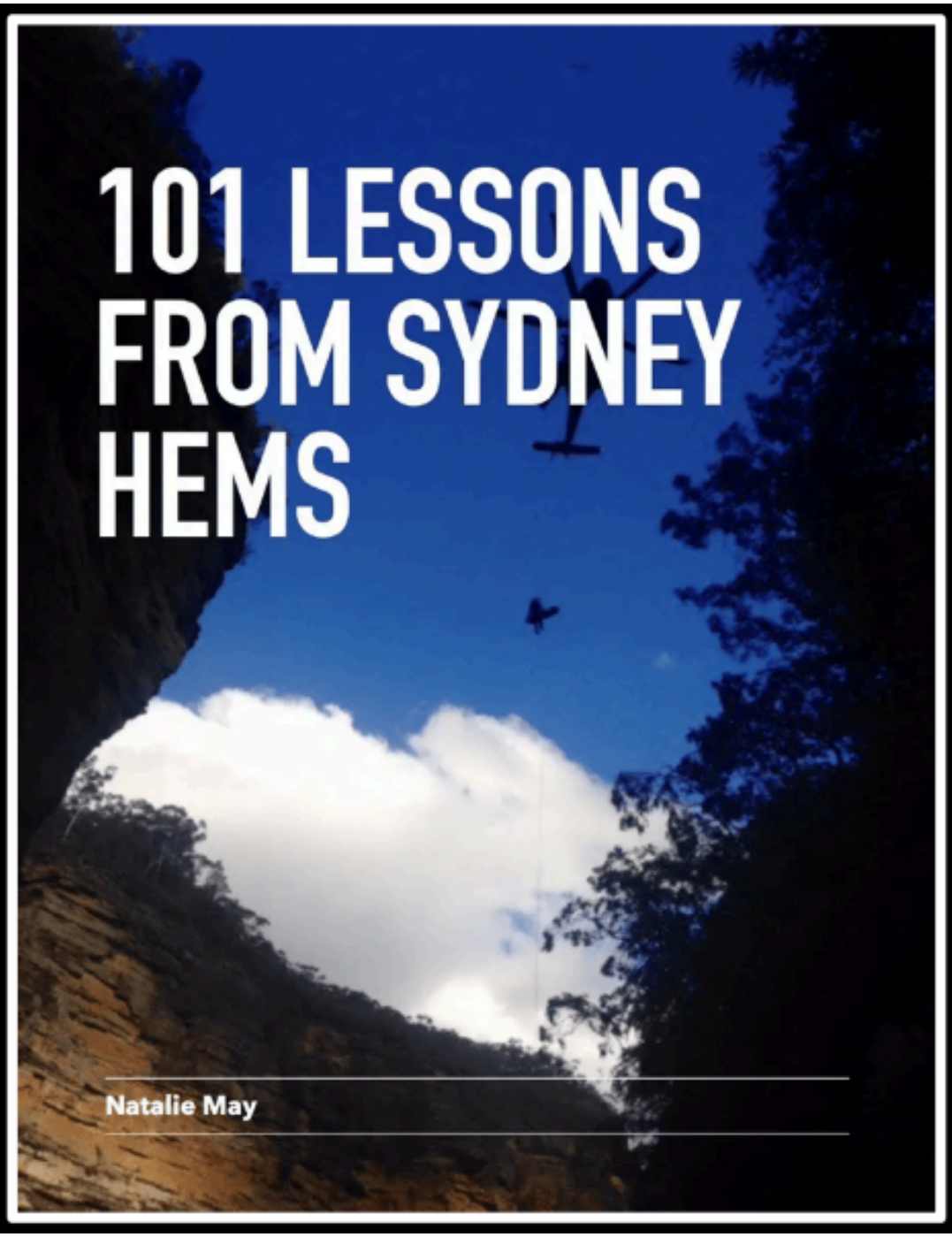
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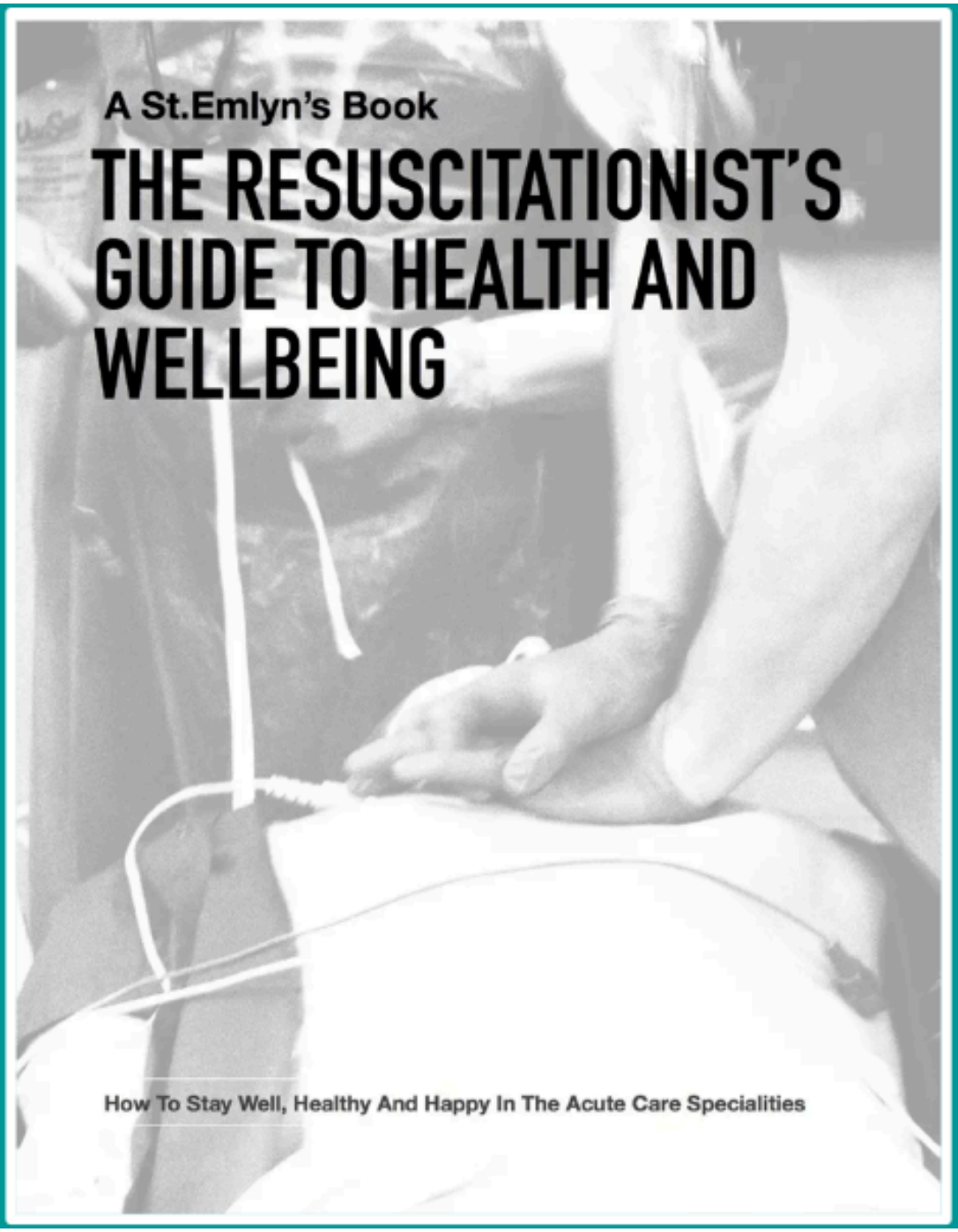
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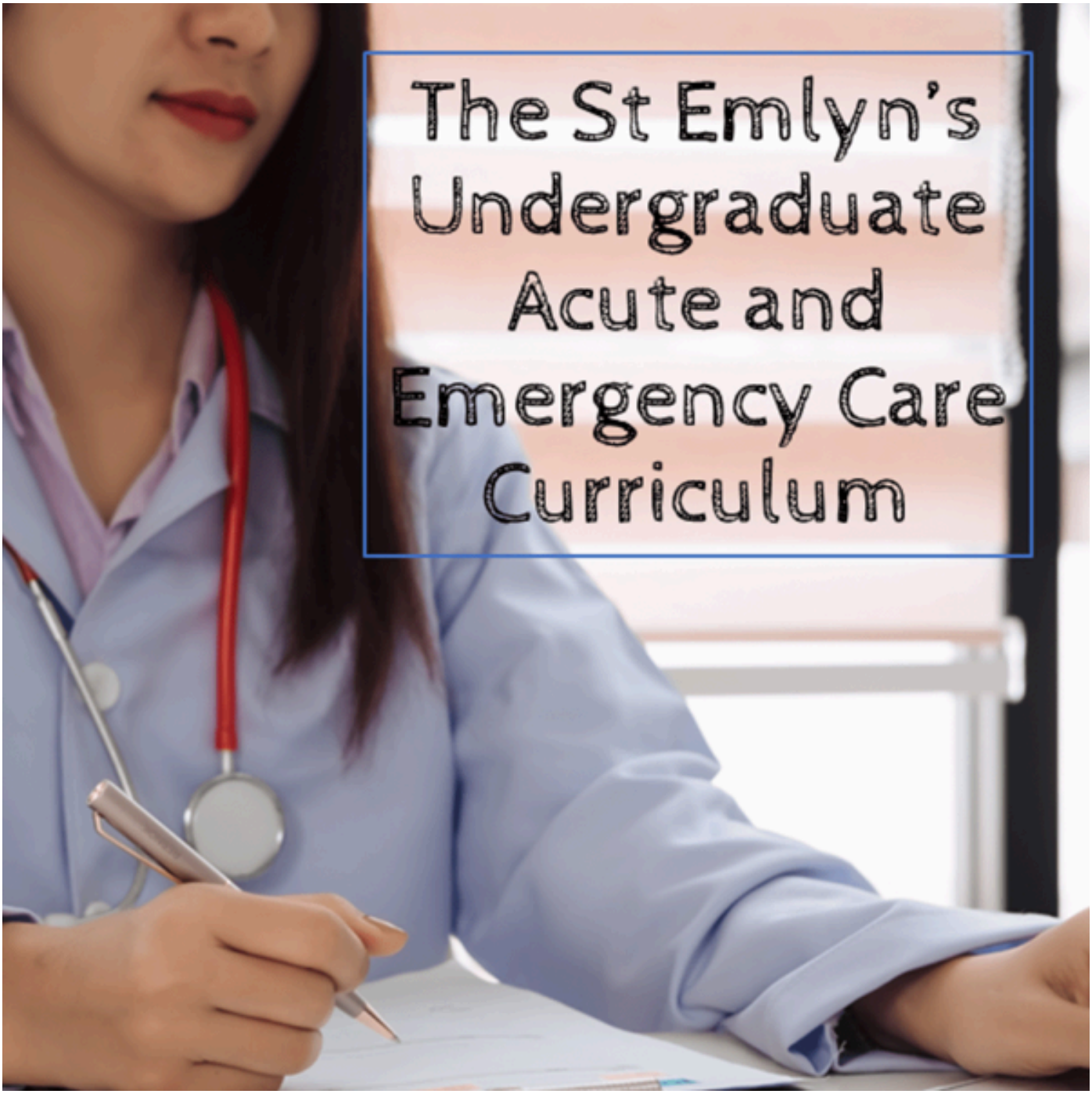

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